DOCUMENT RESUME

ED 269 242 SE 046 558

AUTHOR Feher, Elsa
TITLE Conceptions of Light and Vision: From the Naive to the Expert.
PUB DATE [86]
NOTE 14p.; Paper presented at the Annual Meeting of the American Association of Physics Teachers (Atlanta, GA, January 27, 1986).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS College Students; *Comprehension; *Concept Formation; Elementary Education; Elementary School Students; *Light; *Misconceptions; Preservice Teacher Education; *Science Education; *Science Instruction; *Vision

ABSTRACT

This paper examines work in eliciting conceptions of light and vision that are held by naive learners and about some promising instructional strategies that emerge from this work. Naive learners are defined as subjects that have not had formal exposure to the physics of light, particularly elementary school children who were interviewed in the informal setting of an interactive museum and prospective elementary school teachers in a college science class. Sections of the paper discuss: (1) historical aspects of explanations dealing with visual phenomena; (2) children's conceptions which were elicited during their experiences with museum exhibits (focusing on intermittent and extended light sources); (3) research strategies used to identify children's preconceptions; and (4) a four-step prescription for teaching. This prescription (which involves eliciting, confronting, engaging, and extending) is used with portable, easy-to-make versions of exhibits which are taken to children's workshops and to college classes for preservice teachers. (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

ED269242

CONCEPTIONS OF LIGHT AND VISION; FROM THE NAIVE TO THE EXPERT

BY

Elsa Feher
Natural Science Department
San Diego State University
San Diego, CA 92182

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Elsa Feher
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Talk presented at the Symposium on Instructional Strategies Based on Research, American Association of Physics Teachers (AAPT) January 1986.

SE 046 558

Talk presented at the Symposium on Instructional Strategies Based on Research, American Association of Physics Teachers (AAPT), January 1986

CONCEPTIONS OF LIGHT AND VISION; FROM THE NAIVE TO THE EXPERT

Elsa Feher
Natural Science Department, San Diego State University, San Diego, CA 92182

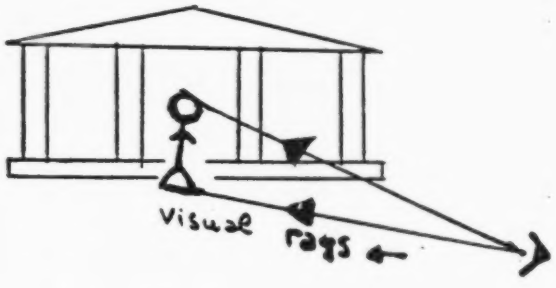
Today I will be telling you about our work in eliciting conceptions of light and vision that are held by naive learners and about some promising instructional strategies that emerge from this work. By naive learners, I mean subjects that have not had formal exposure to the physics of light. In our case, they are elementary school children who are interviewed in the informal setting of an interactive science museum and, also, prospective elementary school teachers in a college science class.

I. History

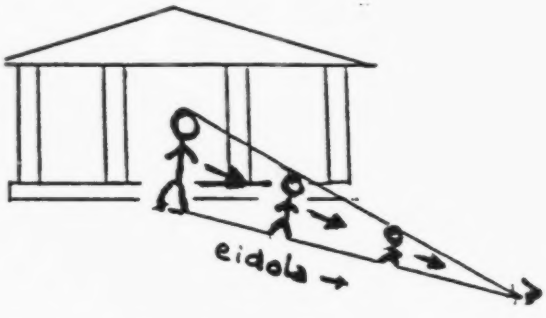
In order to give some perspective to this work I will begin by tracing, in a simplified manner, the evolution in history of our explanations of visual phenomena. In other words, I'll be doing a bit of physicists' history: history that historians frown upon but that physicists find useful for their purposes.

If we go back to the times of the Greeks, we find that there are two schools of thought: one espousing an emission theory of vision, where something is emitted from the eye, the other an intromission theory where something is introduced into the eye.

Emission Theory



Intromission Theory

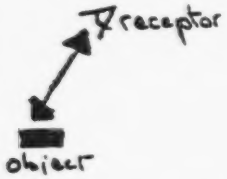


The emissionists (Pythagoras, Euclid, Plato) postulate an effluvium that leaves the eye and apprehends the color and shape of the object.

The intromissionists (Epicurus, Lucretius) assume that an "eidola" or image is emitted by the object and enters our eye. The small images that you see when looking into someone

else's eye were taken to be the reduced essences of the objects themselves.

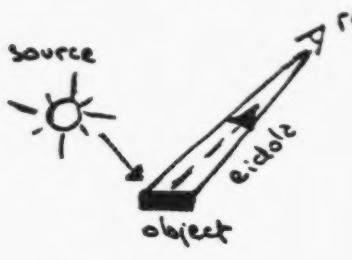
There were, of course, the middle of the roaders, people like Aristotle and Empedocles who thought in terms of two fluxes, one from the object and one from the eye, moving in opposite senses and meeting to produce the effect of seeing. What is intriguing to us is that in these theories, the sun or an external light source does not appear. Euclid, who also studied the light of the sun, considers the behavior of sun rays to be a separate phenomenon, quite apart from his visual ray optics. The Greek models of vision, insofar as they involve only the object and the receptor, can be schematized so:



The Greeks (~400 BC)

Light has no active role

Later on, in the Middle Ages, the Arab School, which was strong in medicine, achieved a better understanding of the anatomy of the eye. This led to the notion that something material -more material than effluvia or eidolas- must enter the eye. The idea was advanced that when common objects are struck by sunlight, they throw back this light in all directions and to our eye. However, how this conveys the object's structure and form to the eye was still not understood. As late as the sixteenth century, a common conception was that the sun, in striking an object, stimulated the emission of the eidola of that object which then was led to the eye by the sun's reflected rays. This notion of the light triggering the object to emit something is also of special interest to us:



The Arabs (~1000)

Light triggers the emission of the image by the object

It is with Kepler that vision is explained in terms of light as we do today. In 1610, Kepler published his book Dioptrice. In it, he states the properties of light and uses reflection and refraction to explain how a point by point image of the object is formed in the retina of the eye. This explanation, wholly in terms of light and its properties, was revolutionary: It is only then, that the idea of an image that detaches itself from the object and

floats to the eye is finally gone. The role of light, object and receptor are finally well understood.

This way of looking at a visual phenomenon is what we call the expert model: to explain what we see, we need to analyze the nature of the light source, follow the path of the light it emits and analyze its interaction with the objects it encounters on its way to the eye; and the nature of the eye/brain receptor must also be understood to ascertain its role in the visual phenomenon:

Kepler (1610)

"Expert" model

II. Our Work

Now that we have reviewed the path from historically naive models of vision to the present day "expert" one, we will take a look at the ways in which children interpret visual phenomena. In our work, the children were in the age range of nine to thirteen years. We carried out individual Piaget-like interviews with them during their visit to our local Science Center. The exhibits in the Science Center are interactive and lend themselves to manipulations, predictions and testing, much like a laboratory activity. The interviews were centered around tasks that were singled out at chosen exhibits.

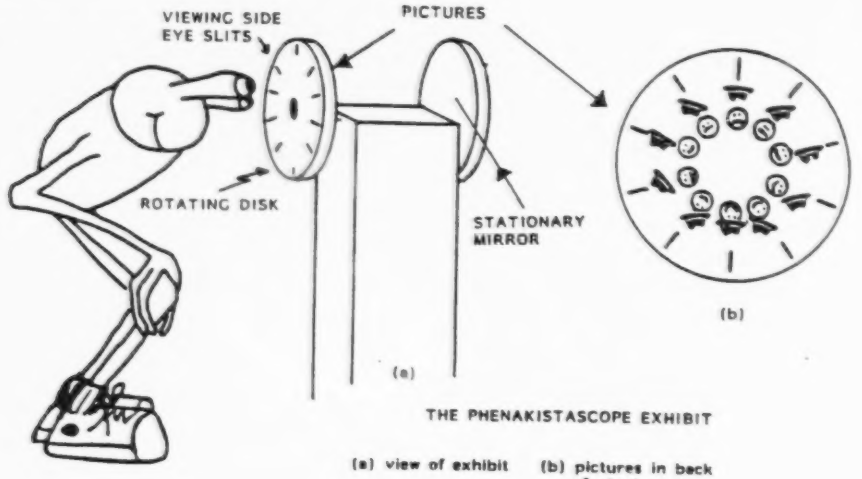
I will describe the exhibits and the effects they show, the protocols used and the resulting answers. As you will see, the answers given by the children show some definite commonalities; certain kinds of verbiage appears again and again. I would like to point out that, for the most part, the children are eager to share their insights with us. We believe that this is due in large measure to the open, unthreatening atmosphere of the Science Center coupled with the drama of the effects shown in the exhibits. More on this later.

A. Intermittent Sources

slits

Our first interviews were carried out at the Phenakistascope, an exhibit in which a wheel carries a cartoon design. When the wheel is rotated, the design appears blurred if you look at it directly. But it appears distinct, like an animated cartoon film, if viewed through rotating slits (there is a mirror in the back). Children (N=20) who were asked "What is going on?" at this exhibit gave explanations of the unblurring effect that involved the object (the drawings) and the observer (who alternately sees and doesn't see). The light, however, was conspicuously absent from the explanations. This is not surprising: Other researchers have also found that children explain visual effects without involving light. And we have already

seen that the Greeks did so too. In these explanations, light enables our eyes to operate but has no active role in the process of seeing.



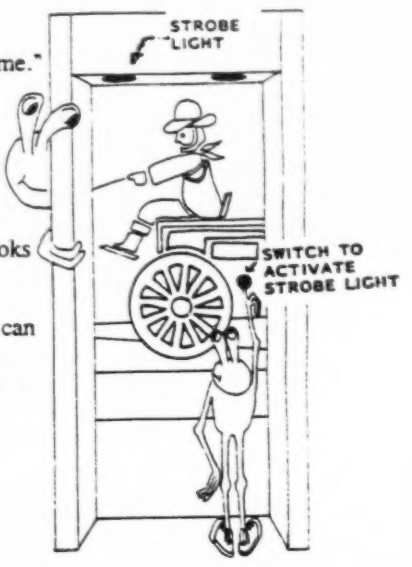
THE PHENAKISTASCOPE EXHIBIT

(a) view of exhibit (b) pictures in back of viewing side

Strobe

This being the case we looked for another exhibit, another phenomenon, that would dramatize the role of the light source. We chose an exhibit consisting of a wheel with painted spokes. When the wheel is rotated, the spokes look blurred. When a stroboscope light is turned on, the spokes appear distinct again and the wheel seems to slowly rotate forwards, stop, and then reverse its motion. We interviewed about twenty children at this exhibit. Here is a set of representative answers when the children are asked "How can you explain this?"

"It looks like it's going slow, but it's going super fast."
"Making dark and light."
"(The light shines) one fraction at a time, shines it on one part at a time."
"It (the light) is making it separate. It separates the spokes."
"Light makes it go slower."
"It (the light) slows it down."
"It (the light) is freezing it like a photograph."
"The light hits it, it gives more light and makes it (the spoke) light."
"The light blinks on it, it shows it where it is."
"It shows the picture in frames. We see one frame at a time and it looks like it's slowing down."
"The light shines on the spoke and makes it look like that."
"It shines on the brown and makes it move. It's an illusion, your eye can deceive you."
"Light shines on it. It goes so fast. It just goes together without light; with light, it makes it separate. With your eye and your brain."
"It flashes from one piece to another. It shows a better picture. It's slowing down for your eye."



THE STROBOSCOPE EXHIBIT

About half of answers we received are of the type of those that are underlined, where the light is described as a force that acts on the wheel to cause the effect: The light is the subject of action verbs ("it makes", "shows", "freezes", "hits", "blinks") and the wheel is the object of the action. Among the answers given, few make reference to a receptor. We can diagram this model so:

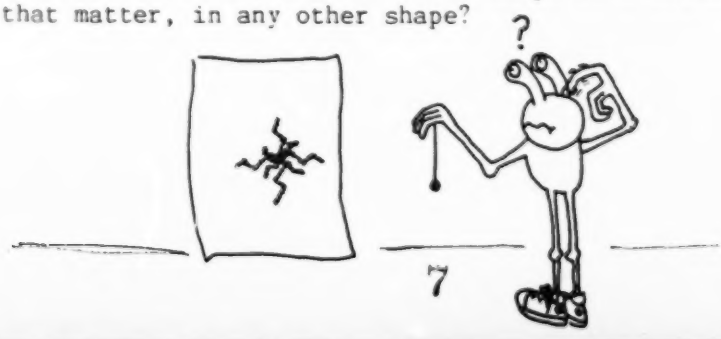
Slits and strobe

What will happen, we asked ourselves, if we somehow coalesce the two exhibits? Will we elicit more answers that include both the receptor and the light source? We fabricated a slitted wheel and interviewed another group, a third set of children (N=20) at the Stroboscope exhibit. The interview consisted of two parts: first, the child experienced the unblurring of the rotating spokes by looking through the rotating slits; then, the slits were put away, the strobe light was turned on, and the child was asked to explain what was going on. Three quarters of the explanations of the strobe effect now brought in the three elements- the light (source), the object and the receptor- although not neccessarily invoking the mechanism of reflection; e.g. "I see the wheel when the light is on." In these explanations light no longer hits, shows, stops the wheel. Light now "blinks like your eye" or "shows you the spokes." So you see how this suggests the importance of expanding children's experience: By allowing them to experience the effect of the slitted wheel and then the intermittent light source, we could elicit more sophisticated explanations.

B. Extended Sources

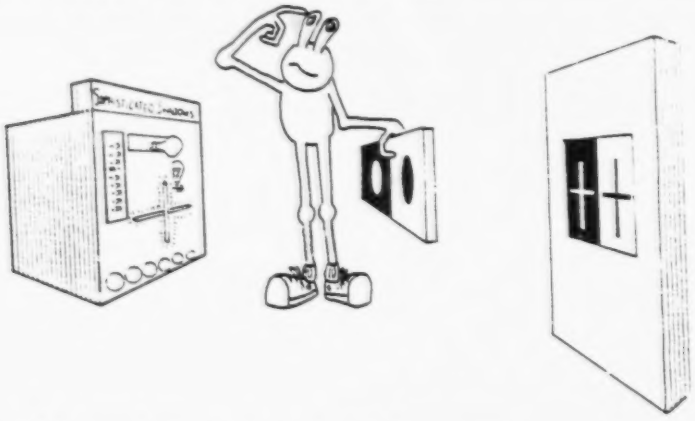
Apart from intermittent light devices there are other types of lights that can be used to dramatize the importance of the light source in a visual effect such as the extended light sources used in an exhibit called Sophisticated Shadows.

This exhibit might best be introduced to you, an audience of physicists (this is not the way we introduced it to the children), by asking a question: Is it possible for a small bead to cast a shadow in the shape of a cross or, for that matter, in any other shape?



The answer is Yes, if the bead is very small compared to the light source and the source is in the shape of a cross.

This is a cartoon version, not to scale, of the exhibit we used. The effects it shows are subtle:



A cross light through a pinhole forms an image on the screen in the shape of a cross. A bead, or small opaque dot, acts like an "anti-pinhole" and on the screen the shadow is an "anti-image" of the source.

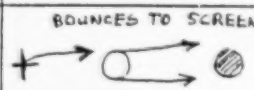
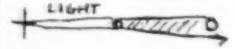
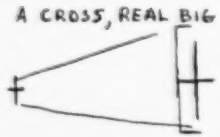
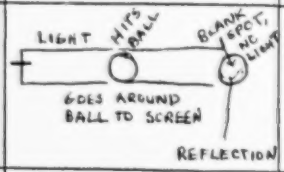
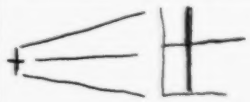
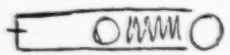
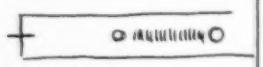
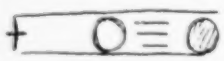
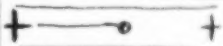
We interviewed about forty children at this exhibit asking for predictions and explanations. They were asked to predict what they would see on the screen

1. if the cross light were turned on
2. if a large ball- a softball- were put in between the cross light and the screen
3. if a small bead were put in between the cross light and the screen

This (see next page) is a collection in matrix form of a few of the children's answers. The protocol runs horizontally at the top. Let me point out a few things (see underlined items in the matrix):

- When referring to shadows. about half the children used the word "reflection" or referred to it as "a dark image" like a reflected image in a mirror. Only one third of the answers referred in some way to the blocking of light to make a shadow.
- The prediction for the shape of the shadow of a round object, big or small, was in almost all the cases a circle. This is as expected since in our everyday experience shadows are usually in the shape of the object that casts them. But it is interesting that even after the shadow of the bead is seen to be a cross about ten percent of the children cling to the notion that the shadow should have the shape of the bead and are reluctant to give it up:

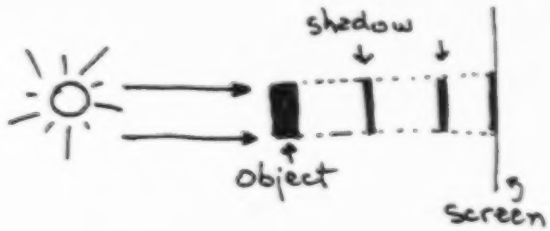
"The shadow is there (behind the bead) but you can't see it; it comes out and gets into the cross."
"The middle of the cross is the bead in the shadow."
"The shadow of the bead is in the middle of the cross."

WHAT IS A SHADOW?	WHAT DO YOU NEED TO MAKE A SHADOW?	WHAT WILL THE SCREEN LOOK LIKE IF WE TURN ON THIS CROSS LIGHT?	WHAT WILL YOU SEE ON THIS SCREEN IF WE PUT THIS SOFTBALL IN FRONT OF THE CROSS LIGHT?	WHAT WILL YOU SEE ON THE SCREEN IF THE BEAD IS IN FRONT OF THE CROSS LIGHT?	EVALUATE: CAN YOU EXPLAIN WHY THE SHADOW IS A CROSS?	BEFORE WE DO THE SOFTBALL, DO YOU WANT TO CHANGE YOUR PREDICTION?
67 13Y B Opposite of light.	Sun, and something to block light.	—			The cross light, it stays like a cross.	—
67 12Y B The reflection from the sun off your body.	Sun, light, object	—			because of the light, the shape gives off another shadow around.	+ O + A CROSS The ball blocks the whole cross. (after evaluation)
65 10Y B Reflection of something, it shows the shape of you.	Something, light				It's distortion.	+ O + BIG CROSS
67 13Y 6 A place where light won't show because it's (object) blocking light.	Light, something				The light goes around it. (object)	I'll keep it the same.
68 13Y B Something on the ground from your body blocking light.	Light, object			—	 Light hits the bead as a cross and does not show the circle part.	+ O +
63 8,9Y 6 When the sun comes to you and your shadow shows	sunlight, something big enough to make a shadow.		DARK PART GOES THIS WAY (→) MOVING (What makes it move? "The light."	The shadow gets bigger, the light makes it bigger and moves it to the wall.	—	—

BEST COPY AVAILABLE

- The verbalizations that go with the diagrams are of interest:
"The light...moves it (the shadow) to the wall."
"The shadow moves until it hits something."
"The light hits the object and the shadow goes to the screen."

What emerges from these interviews is a way of thinking about shadows that is reminiscent of the Arab model of vision. It goes something like this: a shadow is something that belongs to the object and has its shape; the role of the light is to trigger the emission of this object-like shadow to the ground or the screen, not to form it or shape it.



It's the light "hitting" the object that "projects" the shadow. Again, light is endowed with force-like characteristics: the light is a force, the shadow is an object. From the point of view of teaching, this shows the road ahead: to change the conception of shadow as the presence of something tangible to that of shadow as the absence of something (light).

III. Research Techniques

I have given you some examples of preconceptions held by children together with the strategies/techniques that we used in identifying them. Let's take another look at these techniques, independently of subject matter; then we will see how they can be adapted for instruction. (See table next page.) The technique we use entails asking for predictions at a task that is then shown to have a dramatic outcome, and to ask for explanations throughout. We ask for predictions in order to engage the subject intellectually and affectively, to get him/her to think and to commit to an outcome. The dramatic outcome of the task serves to confront the subjects with their previous beliefs through surprise. The element of surprise- pleasant or otherwise depending on whether the prediction was correct or not- acts as a powerful motivator for the subjects to explain, to verbalize their thought processes and to initiate other tasks. These explanations are what we are after in order to get at the subjects' preconceptions.

IV. Instructional Strategies

For instructional purposes we can use the same strategy; but the purpose of each step is inverted. The preconceptions have been identified: This is the role of

STRATEGY/TECHNIQUE

←RESEARCH→			←INSTRUCTION→	
WHAT	WHY	HOW	WHY	WHAT
Engage	To get student to think and to commit	Ask for predictions	T: To diagnose S: To commit to an outcome	ELICIT preconceptions
Surprise, Confront	To motivate, reward, hold attention	Show dramatic outcome	S: To motivate, surprise, intrigue	CONFRONT with own beliefs
Elicit	To get at preconceptions	Ask for explanations (verbal, diagrammatic)	S: To assimilate and accommodate discrepant event into mental structures	ENGAGE the intellect
		Enlarge experience through exposure to other similar phenomena	S: To internalize	EXTEND experience

the researcher. When the teacher asks for predictions, it is to elicit the preconceptions of the students in the class for diagnostic pruposes. As for the students, the predicton amounts to making a bet on the outcome, a commitment that will give each one of them the opportunity of being right and rejoicing or of being wrong and wondering why. The confrontation with the dramatic outcome acts as a powerful motivator for the student to give explanations and engage intellectually - and affectively- in the problem. The phenomenon experienced is assimilated and/or the mental structures shifted to accomodate the discrepant event. The fourth step, to expose the student to other conceptually similar phenomena, has the purpose of extending the students' experience and effectively enabling them to internalize it.

Our four step prescription for teaching, then, is to ELICIT, CONFRONT, ENGAGE AND EXTEND.

We have followed this prescription using portable, easy-to-make versions of the exhibits and taking them to children's workshops and a college class of prospective teachers.* We also use these instructional techniques at the Science Center where we have trained a corps of high school students to act as facilitators, helping the public at large to interact with the exhibits.

Let me conclude by saying that we find our strategies to be powerful and successful. The measure of this is the kind of information they generate and especiallly the high frequency with which we see in our students that gleam in the eye that signals, for the world to see, that an "Aha" experience has just taken place.

* E. Feher and K. Rice "Showing Shadows' Shapes: Activities to Elicit and Dispel Some Preconceptions", Science and Children to be published in Fall 86.

K. Rice and E. Feher "Whirling Wheels and Dripping Drops" in preparaton for submission to Science and Children.